

Prediction of clinical outcomes in elderly patients with hypertension combined with stroke based on CT imaging histology

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Abstract: Objective: To predict the clinical outcome of elderly patients with hypertension combined with stroke based on CT imaging histology. Methods: A total of 260 elderly patients with hypertension combined with stroke admitted during September 2023-January 2025 were analyzed and classified as poor (85) and good (175) by mRS score, clinical and imaging data were collected and compared, logistic regression analyzed the risk factors of patients, and R software constructed a column-line graph model to assess the model prediction efficacy with calibration, ROC, and decision curve with Consistency. Results: Logistic regression modeling analyzed uric acid, HCY, hyperlipidemia, diabetes mellitus, blood pressure variability, creatinine, black hole sign, shape irregularity, midline shift, and density inhomogeneity as risk factors influencing the occurrence of clinical outcomes in patients ($P < 0.05$); The Hosmer-Lemeshow goodness-of-fit test of the column-line graph model fit is high; the ROC curve analyzes the predictive efficacy of the column-line graph prediction model is good. Conclusion: CT imaging histology is effective in predicting patient clinical outcomes with high predictive efficacy.

Keywords: CT imaging histology; hypertension; stroke; clinical outcome

Hypertension is a common chronic cardiovascular disease. Long-term unstable blood pressure control can cause serious harm to the body. However, as age increases, the vascular elasticity of stroke patients decreases, leading to vascular degeneration and thus increasing their risk of disease. Moreover, for hypertensive patients with stroke, the blood pressure fluctuation situation is more complex^[1,2]. Therefore, early identification and detection to optimize treatment decisions have become an urgent problem to be solved in clinical practice. Computed tomography (CT) is a commonly used imaging method in clinical screening and diagnosis. Radiomics can extract quantitative features from medical images using high-throughput analysis methods and characterize the heterogeneity of diseases with effective features. It has been applied in clinical diagnosis differentiation and prognosis prediction and is currently a research hotspot in clinical practice^[3,4]. However, no systematic study has yet explored the value of CT radiomics prediction for elderly patients with hypertension complicated with stroke.

Based on this, this study aims to analyze the clinical outcomes of CT radiomics in predicting elderly patients with hypertension complicated with stroke.

1. Materials and methods

1.1 Research Object

The relevant data of a total of 102 elderly patients with hypertension complicated with stroke admitted to our hospital from September 2023 to January 2025 were analyzed, and the patients were divided into the poor prognosis group and the good prognosis group according to the clinical outcomes. Moreover, this study has been reviewed and approved by the Medical Ethics Committee of our hospital.

Inclusion criteria: ① The initial diagnosis of elderly hypertension combined with stroke by CT imaging is based on the "National Guidelines for the Prevention and Management of Hypertension in Primary Care (2020 Edition)" for hypertension, and the stroke meets the standards of the "Guidelines for the Diagnosis and Treatment of Ischemic Stroke in Primary Care (2021 Edition)"^[5,6]; ② The time from the onset of the disease to admission for treatment is less than 1 day. ③ The patient or their family members are willing to participate in this study and sign the informed consent form; ④ The clinical and follow-up data are complete.

Exclusion criteria: ① Those with liver or kidney function disorders; ② Those who have cognitive dysfunction such as mental illness or Alzheimer's disease before the operation; ④ Those with concurrent malignant tumors in other parts of the body; ⑤ Patients who failed to complete the follow-up for various reasons.

1.2 Follow-up

All patients underwent CT examinations. The scan images were transmitted to the post-processing workstation and exported in DICOM format. Three months later, the clinical outcome of the patients was measured by the modified rankin scale (mRS)^[7]. $mRS \leq 3$ indicated a good prognosis, and $mRS > 3$ indicated a poor prognosis, which was obtained through patient reexamination, hospitalization records or follow-up, etc.

1.3 Data Collection

Clinical data characteristics of patients collected: including patients' age, gender, smoking history, BMI, prothrombin time, cholesterol, high-density lipoprotein, uric acid, diabetes, HCY, high-salt diet, blood pressure variability, hyperlipidemia, creatinine, etc. (1) Determination of test index levels: 4ml of fasting venous blood from the patient was collected at 8 a.m. and centrifuged (at a speed of 3000r/min; Centrifugal radius: 10cm; Centrifuge for 10 minutes, separate the serum and store it at -75 °C for testing. Strictly follow the operation instructions

of the reagent kit. Serum creatinine, prothrombin time, cholesterol and high-density lipoprotein levels are detected by an automatic biochemical analyzer.

1.4 CT Scan

(1) A multi-slice spiral CT machine was used for scanning in the state of holding one's breath after complete inhalation. Parameters: tube current 50-350 mA, tube voltage 120 kV, detector collimation 128×0.625 mm or 64×0.625 mm, layer thickness 2.5 mm, matrix 512×512, field of view 350 mm×350 mm. All images were obtained from the Image Archiving and communication system workstation and retrieved in DICOM format.

(2) Image analysis and feature extraction: Two physicians with over five years of working experience independently analyze and extract radiomics features. The images were analyzed using 3 Dslicer software. The region of interest was continuously delineated on the cross-section, and the required images were automatically drawn according to the threshold, which was set from 50 to 110HU. Omics feature extraction was carried out using the PyRadiomics3.0.1 plugin tool, from which 963 radiomics features (wavelet features, first-order features, shape features, texture features, gray-level co-occurrence matrix features, gray-level size region matrix features, and gray-level dependency matrix features) were extracted. The repeatability of its extraction was evaluated, and the inter-group and intra-group correlation coefficients (ICC) of radiomics features were calculated. An ICC > 0.75 was considered to have good consistency. On the basis of the original features, processing normalization is carried out. The features are transformed to the range of (-1, 1) by the maximum absolute value normalization method. The image dimension is reduced by algorithms such as the minimum absolute value shrinkage and selection operator (LASSO) and the optimal feature screening to screen out the image omics features with better predictive value. And the radiomics score (Rad-score) was established through the weight coefficient^[8].

1.5 Statistical Methods

The data were analyzed using SPSS 25.0 statistical software. The count data were expressed as frequency (n, %) and tested by χ^2 . Measurement data conforming to normal distribution were expressed as ($\bar{x}$, s). Independent sample t-tests were used. For variables with $P < 0.05$ in the results of univariate analysis, Logistic regression was used to screen for influencing factors affecting the clinical outcomes of elderly patients with hypertension complicated with stroke. The coefficient of variance inflation (VIF) was used to evaluate collinearity, and a predictive nomogram model was constructed. The Hosmer-Lemeshow test was conducted. The area under the ROC curve (AUC), calibration curve, and decision curve were used to evaluate the consistency and clinical benefits of the model, respectively. $P < 0.05$ indicates a statistically significant difference.

2 Results

2.1 Univariate analysis of clinical outcomes in elderly patients with hypertension complicated with stroke

As shown in Table 1, there were no statistically significant differences in age, gender, smoking history, BMI, prothrombin time, cholesterol, and high-density lipoprotein between the good prognosis group and the poor prognosis group ($P > 0.05$). Moreover, there were statistically significant differences in uric acid, HCY, hyperlipidemia, diabetes, high-salt diet, blood pressure variability, and creatinine ($P < 0.05$).

Tab 1. Univariate analysis of the occurrence of clinical outcomes in elderly patients with hypertension combined with stroke ($\bar{x} \pm s, \%$)

Groups		Good prognosis group(n=175)	Group with poor prognosis(n=85)	t/X ²	P
Age(year)		59.70±6.19	60.03±6.22	0.403	0.688
Gender(Male/Female)		100/75	55/30	1.359	0.244
Uric acid(μmol/L)		281.98±72.07	338.46±82.63	7.216	<0.001
HCY(μmol/L)		22.58±4.37	29.73±5.62	11.237	<0.001
Smoking history		50(28.57)	30(35.29)	3.307	0.069
BMI(kg/m2)		22.83±2.52	22.71±2.60	0.357	0.722
Hyperlipidemia	Deny	142(81.14)	49(57.65)	16.201	<0.001
	Correct	33(18.86)	36(42.35)		
Diabetes mellitus	Deny	136(77.71)	44(51.76)	18.085	<0.001
	Correct	39(22.29)	41(48.24)		
High-salt diet	Correct	129(73.71)	39(45.88)	19.383	<0.001
	Deny	46(26.29)	46(54.12)		
Blood pressure variability	Correct	52(29.71)	55(64.71)	28.926	<0.001
	Deny	123(70.29)	30(35.29)		
Prothrombin time(s)		11.80±1.71	12.23±1.93	1.823	0.070
Cholesterol(mmol/L)		4.52±1.24	4.39±1.21	0.799	0.425
High density lipoprotein(mmol/L)		132.77±33.90	133.13±33.96	0.080	0.936
Creatinine(μmol/L)		76.03±15.82	98.39±21.25	9.517	<0.001

2.2 Compare the changes of CT radiomics characteristic indicators between the two groups

As shown in Table 2, compared with the good prognosis group, there were statistically significant differences in the irregular shape, black hole sign, midline displacement, uneven density and island sign of patients in the poor prognosis group ($P < 0.05$).

Tab 2. Comparison of changes in histological feature indicators between two groups of CT images(n,%)

Groups	Number of cases(n)	Irregular shape	Black hole sign	Midline shift	Uneven density	Island Expedition
Good prognosis group	175	43(24.57)	22(12.57)	19(10.86)	38(21.71)	15(8.57)
Group with poor prognosis	85	49(57.65)	30(35.29)	39(45.88)	47(55.29)	19(22.35)
X ²		27.375	18.462	40.496	29.318	9.560
P		<0.001	<0.001	<0.001	<0.001	0.002

2.3 Multivariate Logistic regression analysis was conducted to analyze the related factors influencing the clinical outcomes of elderly patients with hypertension complicated with stroke

As shown in **Table 3**, whether the clinical outcome occurred in elderly patients with hypertension complicated with stroke was taken as the dependent variable (good =0, bad =1), and the independent variables were included. Considering that there is a certain correlation and collinearity among the independent variables, in order to avoid overfitting of the model, the independent variables were subjected to dimensionality reduction processing. Among them, VIF>10 for age, gender, smoking history, BMI, prothrombin time, cholesterol, high-density lipoprotein, high-salt diet, and island sign showed multicollinearity among variables and were excluded from the model. The final Logistic regression model retained that uric acid, HCY, hyperlipidemia, diabetes, blood pressure variability, creatinine, black hole sign, irregular shape, midline shift, and density inhomogeneity were all risk factors affecting the clinical outcomes of elderly patients with hypertension complicated with stroke (P<0.05).

Tab 3. Multivariate logistic regression analysis of factors influencing clinical outcomes in elderly patients with hypertension and stroke

Influence factor	β	SE	Wald x ²	P	OR	95%CI
Uric acid	1.063	0.496	4.953	<0.001	2.895	1.903~3.887
HCY	0.969	0.336	8.317	<0.001	2.635	1.963~3.307
Hyperlipidemia	1.228	0.474	6.712	<0.001	3.414	2.466~4.362
Diabetes mellitus	1.396	0.669	4.354	<0.001	4.039	2.701~5.377
Blood pressure variability	1.404	0.717	3.834	<0.001	4.071	2.637~5.505
Creatinine	1.195	0.530	5.084	<0.001	3.304	2.244~4.364
Black hole sign	1.006	0.319	9.945	<0.001	2.735	2.097~3.373
Irregular shape	1.055	0.363	8.447	<0.001	2.872	2.146~3.598
Midline shift	1.069	0.401	7.107	<0.001	2.912	2.110~3.714
Uneven density	1.476	0.722	4.179	<0.001	4.375	2.931~5.819

2.4 Radiomics Feature Selection and Model Construction

As shown in **Figure 1**, 963 radiomics features were extracted from CT images. Features with ICC < 0.75 were deleted. 25 features with high correlation and no redundancy were screened out by the method of minimum redundancy and maximum correlation. Finally, 10 best features were screened out by LAS-SO regression. By selecting the linear combination of features Generate Rad-score= $7.336 \times$ pre-admission uric acid $+1.022 \times$ pre-admission HCY $+0.727 \times$ combined hyperlipidemia $+1.172 \times$ combined diabetes $+1.040 \times$ blood pressure variability $+0.779 \times$ creatinine $+0.696 \times$ black hole sign $+0.247 \times$ irregular shape $+1.313 \times$ midline shift $+1.0$ The density is uneven at $80 \times$.

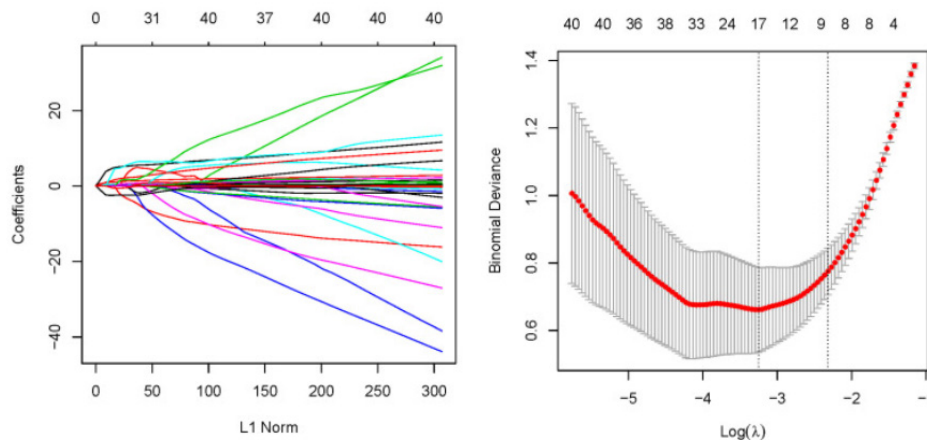


Fig 1. Feature selection for dimensionality reduction and cross validation using Lasso regression

2.5 Model Establishment and Evaluation

As shown in **Figure 2**, the independent predictive factors screened above were incorporated into the prediction model using R software and a nomogram prediction model was constructed. After the Hosmer-Lemeshow goodness-of-fit test, the nomogram model had a relatively high degree of fit ($\chi^2=4.039$, $P=0.507$), and the consistency index was 0.796. Great importance should be attached to the prevention of such patients, and the occurrence of adverse clinical outcomes should be avoided as much as possible. As shown in Figures 4 and 5, the accuracy of the nomogram model in predicting the clinical outcome risk of elderly patients with hypertension complicated with stroke was verified. Through the Bootstrap resampling method, the C-index reached 0.802, indicating that the model has a high degree of excellence distinction. The ROC curve of the model was plotted. The AUC was 0.780, the sensitivity was 83.43%, the specificity was 67.06%, and the accuracy was 78.08% ($P < 0.05$, 95%CI: 0.667-0.893), indicating that the model had good accuracy. Moreover, the slope of the calibration curve being close to 1 indicates that the risk predicted by the model is basically close to the actual occurrence, and the predictive ability is good. To evaluate the clinical effective value of the model, the clinical effect was evaluated by the decision curve graph. The model performed well when the predicted risk value was

between 3.2% and 90%.

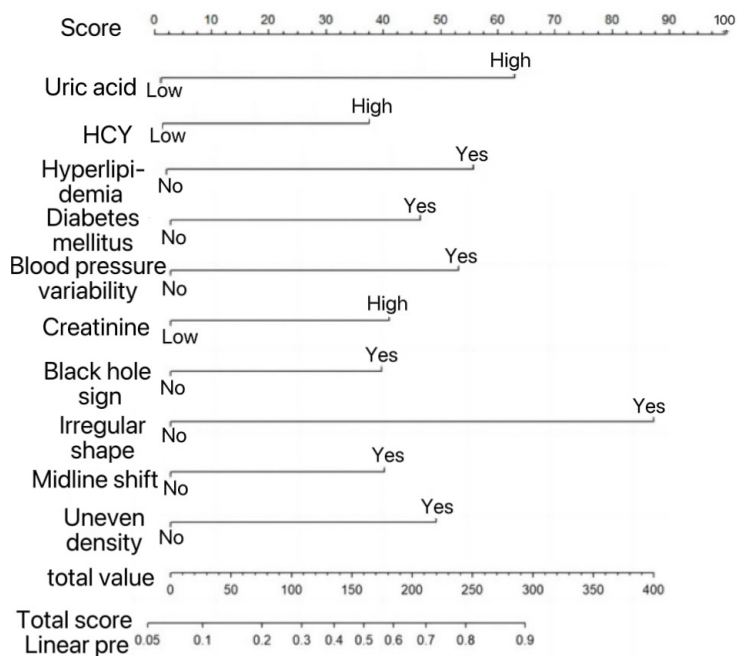


Fig 2. Column line chart model

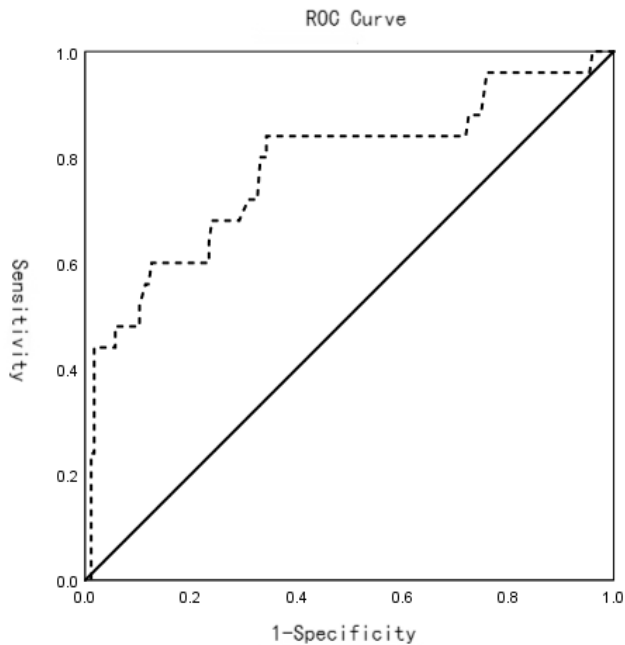


Fig 3. ROC curve of prediction model

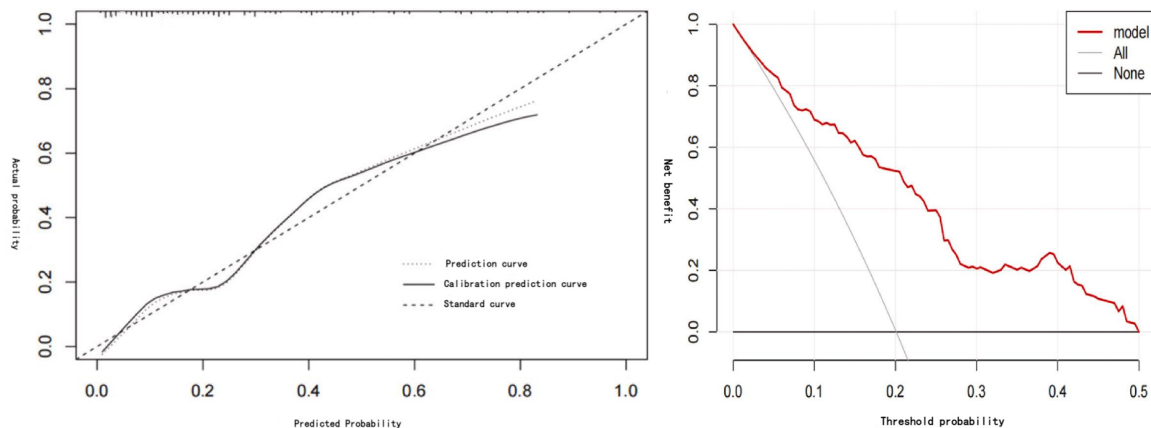


Fig 4. Calibration and Decision Curve of Prediction Model

3 Discussion

This study shows that there are differences in uric acid, HCY, hyperlipidemia, diabetes, high-salt diet, blood pressure variability, and creatinine. Moreover, multivariate regression analysis indicates that these are independent risk factors affecting the adverse clinical outcomes of elderly patients with hypertension complicated with stroke. The possible mechanism suggests that after the occurrence of hypertension combined with stroke, significant changes occur in cytokines in the blood, short-term inflammatory responses intensify, and hypoxia in the brain initiates oxidative stress, promoting the onset of ischemic stroke. Creatinine is related to the glomerular filtration capacity in the body. When the glomerular filtration rate decreases, the level of serum creatinine increases, and serum creatinine can reflect renal function impairment. Blood pressure will further increase after renal function declines^[9,10]. Therefore, conducting renal function tests on elderly patients with hypertension complicated with stroke and avoiding the use of drugs with significant renal toxicity are meaningful for improving their prognosis. This study shows that high levels of HCY are risk factors affecting the clinical outcomes of patients (OR=2.635), which can increase the risk of hypertension. Elevated HCY levels can cause damage to vascular endothelial cells, disrupt the balance between fibrinolysis and coagulation, induce thrombosis, and subsequently lead to stroke. In addition, a high-salt diet is associated with elevated blood pressure, which directly damages vascular function and increases blood pressure, promoting the risk of cardiovascular and cerebrovascular diseases. Therefore, controlling salt intake is beneficial for improving the prognosis of patients with hypertension complicated with stroke^[11,12]. Moreover, the combination of hyperlipidemia and diabetes is the main factor affecting hypertension combined with stroke (OR=3.414, 4.039). It not only increases the incidence of stroke, but also aggravates the condition of stroke patients, hinders their recovery, and leads to a poor prognosis for patients. Therefore, in clinical practice, the clinical conditions of such patients should be given special attention, and timely detection and inter-

vention should be carried out to improve the clinical outcomes of the patients.

This study innovatively analyzed CT radiomics and Logistic regression analysis, which identified black hole sign, irregular shape, midline displacement, and inhomotropy as risk factors affecting the clinical outcomes of elderly patients with hypertension complicated with stroke. It indicates that through CT imaging examination, the irregular shape, midline displacement, and bleeding location of the patient's disease can be understood, and the disease can be accurately determined. And conducting a prospective analysis of prognosis is helpful for clinical practice to formulate effective and scientific treatment plans. In addition, this study also utilized CT images to screen out radiomics features for prediction, and constructed a nomogram risk prediction model. The Hosmer-Lemeshow goodness-of-fit test showed a good fit. Moreover, the ROC and calibration curves indicated that the prediction model had a good consistency with the observed results. The reason for this is that the nomogram is a simple and effective visualization tool. After the prediction model is visualized through the nomogram, it becomes a convenient and reliable way to quantify individual risks. CT radiomics, as a non-invasive method for obtaining quantitative features from medical images, can reduce human errors caused by strong subjectivity. It can transform visual image information into deep-level features for quantitative analysis. For instance, its features can reflect the significance and roughness of gray level changes in the image and measure the spatial change rate of gray level intensity in the image. When its value is relatively high, It indicates that there are obvious gray level changes in the image, that is, the image texture is more uneven and rough. Therefore, by quantifying these features, more detailed information about the lesion can be obtained, and the biological characteristics of the lesion can be understood more deeply, which is of great significance for the evaluation of the therapeutic effect and clinical outcome of the disease^[13-15]. However, this study still has certain limitations: Firstly, the sample size is small and it is a single-center design, which may introduce selection bias; Secondly, due to the relatively short observation period, there might be omissions in the included factors. In the future, it is necessary to expand the sample size and conduct longitudinal studies to verify the conclusion.

In conclusion, the risk factors influencing the clinical outcomes of elderly patients with hypertension complicated with stroke are diverse. Therefore, early prediction of the population with susceptible factors is meaningful. Moreover, the CT radiomics prediction model has achieved better predictive accuracy for the clinical outcomes of elderly patients with hypertension complicated with stroke, which can help clinicians quickly identify the adverse clinical outcomes of patients. It provides new ideas for clinical analysis.

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